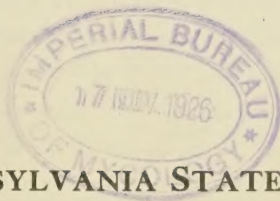


Murrie, J H

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**THE PENNSYLVANIA STATE COLLEGE**  
**SCHOOL OF AGRICULTURE**  
**Agricultural Experiment Station**

**TOMATO LEAF SPOT**  
**AND**  
**EXPERIMENTS WITH ITS CONTROL**

**STATE COLLEGE, CENTRE COUNTY, PENNSYLVANIA**

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# Tomato Leaf-Spot

and

## Experiments With Its Control

By J. H. MUNCIE\*

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### INTRODUCTION

In Pennsylvania there is a considerable acreage devoted to the tomato crop for market and canning purposes. In the northwestern portion of the state, where the work here reported was carried on, the crop is grown mainly for the canning industry, although a part of it may be used for market purposes. The leaf-spot disease, while prevalent throughout the state, has been studied by the writer only in the region bordering upon Lake Erie. In this region the disease appears annually, causing serious defoliation of the plants with a consequent reduction in quantity and size of fruit.

This report is the result of three years of work at the Pennsylvania Agricultural Experiment Station Field Laboratory, Girard, Pennsylvania, and on the farm of C. A. Eagley and Son of North Girard.

### THE HOST RANGE

So far as is known the leaf-spot disease attacks only the cultivated tomato and the common horse nettle (*Solanum carolinense* L.) (15) under natural conditions. There is seemingly very little difference in susceptibility of the different varieties to the disease. The following varieties have been grown or observed with practically no difference in their susceptibility to the leaf-spot disease: Chalk's Early Jewel (3 strains), Bonny Best, Columbia, Arlington, Marvel, Wisdom, Greater Baltimore, Bloomsdale, Delaware Beauty, Earliana, Landreth and Mid-season. Levin (11) reports no cases of particular susceptibility or resistance in the many varieties tested from commercial seed houses. Practically the same results were noted by J. B. S. Norton (7) in his work on varietal resistance to the disease.

### THE DISEASE

**Name.**—There are several names applied to this disease in Pennsylvania and other states where it is common. The names usually applied are "blight" and "leaf-spot". The former is not so well chosen as the latter, especially in regions where

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\* The writer wishes to express his appreciation to C. A. Eagley and Son for their hearty cooperation which made the field experiments possible; also to J. R. Eyer, Field Entomologist of the Girard Laboratory, and W. C. Eagley for taking data on yields during the writer's absence in 1919 and 1921, and to Professor C. R. Orton of the Botany Department of The Pennsylvania State College for aid in revising the manuscript. Contribution from the Department of Botany No. 41.

the late blight caused by *Phytophthora infestans* (Mont.) deBy. is common. The name leaf-spot is most frequently employed to designate the disease.

**Economic Importance.**—The losses to the tomato crop from this disease vary considerably with the conditions under which the crop is grown. In the greenhouse where it has come under the writer's observation it has never attained the destructiveness to the foliage that it does in the field, nor is the plant so severely attacked or quickly killed as is the case with the Fusarium wilt. Under favorable conditions for the development of the disease in the field, losses of as much as 40 per cent of the crop have been reported in Maryland.\* In Pennsylvania in 1919\* it was estimated that approximately 3 per cent of the crop was lost through the disease. This loss amounted to approximately 296 tons. Besides the production of small, watery, acid fruit as the result of the disease, there is also a further reduction in yield rarely apparent to the grower—through the dropping of the blossoms from severe pedicel infection.

**Distribution.**—Septoria leaf-spot of the tomato has been reported as occurring in all states of the United States with the following exceptions, viz.; Montana, Wyoming, Utah, Nevada and Idaho. It is also known to occur in England, France, Australia, Canada, Argentina, Transvaal, Austria, Hungary and Germany, and probably in other countries where the crop is of economic importance and weather conditions are favorable for its development. It is probably the most widely spread of all the diseases of the tomato.

## FIELD APPEARANCE

A field of tomatoes severely attacked by this disease presents a striking appearance. Instead of the normal luxuriant foliage, dark green in color and almost or quite covering the spaces between rows, the leaves turn yellow or brown and the plants become almost defoliated. Usually the plant succeeds in pushing out a few terminal leaves ahead of the attacks of the causal fungus giving it a characteristic brush effect. This appearance in a badly diseased field probably has led to the use of the term blight as a name for the leaf-spot.

**On the Leaves.**—The first symptoms of the disease are apparent upon the lower surface and later upon the upper surface of the leaf as minute dark green, water-soaked spots. The spots gradually enlarge in diameter but retain a circular outline. A well defined margin separates the diseased spots from the surrounding healthy tissue. The affected areas gradually become brown with the shrinkage of the tissue within the spot. Later this portion of the leaf takes on a grayish cast becoming dry and more or less brittle. The spots may vary in size from that of a pinhead to several millimeters in diameter. It is not uncommon to observe several spots which have coalesced to form a large irregular lesion on the leaf. With the loss of water and dying of the affected tissue the pycnidia,

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(\*) These estimates of losses were published in Plant Disease Bulletin. Supplement 6: 205, 1919.

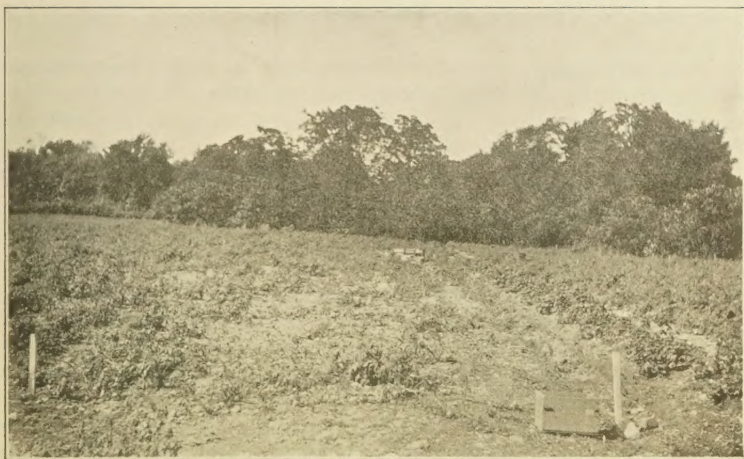


Fig. 1. A photograph, taken September 25th, of an unsprayed plot showing how the disease defoliates the plants toward the end of the season. The yield of ripe fruit is greater, however, than on the field sprayed plots.

or fruiting bodies, of the causal fungus appear. These are minute black, more or less glistening bodies, which, when mature, contain large numbers of the spores of the fungus.

**On the Stems.**—The course of the disease on the stems follows closely that on the leaves. On the green or growing stems the spots are circular or slightly elongated in shape and dark brown to black in color. There is not at first the drying of the stem tissue such as appears on the leaf. However, later in the season, when the leaves have fallen, the diseased areas on the old plants appear as grayish-white spots within which the characteristic fruiting bodies are formed. The spots upon living stems have not been observed to penetrate further than the woody portion. Sporulating pycnidia upon the stems may furnish another source of infection for the young leaves on the plant.

**On the Blossoms.**—The disease has been frequently observed upon the calyx and pedicels of the flower. When infection is severe it results in a dropping of the blossoms. When the sepals alone are infected the blossoms often shrivel and later drop. Blossom infection no doubt causes a reduction in the set of fruit which is more or less serious, but is seldom noticed by the grower.

**On the Fruit.**—So far as the writer has observed, the fruit of the tomato is not affected by the disease in the locality where this work was done. However, Gussow (8) states that as a result of inoculation experiments the fruit was spotted. Floyd (5) states that infection of the young green fruit takes place under the growing conditions of Missouri. Norton (14) reports fruit infection in Maryland. Fruit infection seems the exception rather than the rule in most instances, and cannot be regarded as a constant characteristic of the disease.

## ETIOLOGY

The causal organism of tomato leaf-spot was first described as *Septoria Lycopersici* in 1882 by Spegazzini (19), who also gave a description of the disease. Since that time many investigators have worked with the disease but few have published any proof of the causative nature of the fungus associated with it. Delacroix (2) and Güssow (8) both performed infection experiments with the fungus which they isolated from the lesions but their work did not follow the rules of proof as set down by Koch (10). Levin (11) seems to be the first investigator to satisfy these rules of proof with the fungus causing the tomato leaf-spot.

Isolations of the causal fungus were made by the writer from spots upon old stems after the picking season had ended and while the plants still remained in the ground. The stems, after disinfection with mercuric chloride solution 1:1000, were placed in a sterile moist chamber until the pycnidia upon them began to sporulate. Portions of the spore masses were transferred to tubes of sterile distilled water and from these poured corn meal agar plates were made. In this medium growth was rapid and in about three weeks the pycnidia in the culture plates were sporulating abundantly. Spores from these cultures were used in making inoculations by brushing the inoculum upon the leaves of healthy plants grown in the laboratory. Seven days after inoculation typical spots appeared. About ten days later pycnidia appeared within the spots. Re-isolation of the fungus from the spots upon the leaves was made, and a comparison of the fungus in the cultures with that in the infected spots and with the original cultures showed the organism to be identical in each case.

**The Spore.**—The spores of *Septoria Lycopersici* Speg. are hyaline and filiform varying from 52 to 120 microns in length and from 1 to 4 microns in width. They are generally uniform in width throughout their length, the ends being acute to slightly rounded in shape. Septation varies rather widely, in some cases three septa being present while in others as many as nine were observed.

**The Mycelium.**—The young or immature mycelium is hyaline, thin walled, septate, and frequently vacuolate varying slightly in width but usually of about the same diameter as the spores. The old mycelium is brownish to almost black, thick walled, more closely septate and of considerably larger diameter. The latter type of mycelium is found associated with the pycnidium, while the former may be regarded as purely vegetative preceding pycnidial development.

**The Pycnidium.**—The pycnidium is the only fruiting body so far observed in cultures of this fungus. It is formed by the interweaving and "balling-up" of the thick-walled hyphae. The hyphae form a more or less globose body with walls from 2 to 5 microns in thickness. This body enlarges and within it the short, erect, slightly differentiated conidiophores appear. Upon these are borne the long filiform hyaline spores. When the spores mature the pycnidium bursts, usually at the apex of the body, although in culture, eruption at the side or bottom has been frequently observed and the fruiting body contains only a single cavity. The pycnidia vary in diameter from 85 microns to 350 microns. On the

leaves they appear as black dots protruding from the dead area within the diseased spot. The white to creamy, more or less glistening spore masses are expelled from them. The spores are extruded in a gelatinous mass and in this condition they are held together until dissolved by moisture in some form.

### SPREAD OF THE DISEASE IN THE FIELD

During the three years of field work in connection with the leaf-spot disease it was noted that infection started from a relatively few plants and from these as foci the disease spread over the entire field despite efforts at control by the application of various fungicides. In making records of the spread of the disease, infection was recorded when only one leaflet with the characteristic spot upon it was found. There were of necessity varying degrees of infection, which will be brought out in the tables showing relative percentages of infection per plot.

In the field work it has been found that the leaf-spot disease makes its appearance in this region within narrow time limits during the early part of July, usually from the third to the eleventh, although it may have appeared earlier in other fields.

The writer has made careful observations at the time the seedlings were transplanted to the cold frame and the plants from the cold frame to the field. In only one season did he find any infected plants and in this case there was only one out of 900 used in the experiment. In our experiments the soil of the seed bed and the cold frames was drenched with a solution of formaldehyde 1-240 before planting or transplanting, and the plants in most cases were sprayed with either Bordeaux 2-2-50 or Bordeaux soap 2-2-3-50, before setting in the field. The diseased plant, in the cold frame above mentioned, was noted in the block sprayed with Bordeaux 2-2-50, while no disease was found upon any of the plants which were unsprayed.

### MEANS OF DISSEMINATION

**Seed as a Source of Inoculum.**—Many attempts have been made to find spores of *Septoria Lycopersci* in the water from centrifugalized commercial seed but without success. The spores of the fungus are easily distinguished from all others found so that if they had been present they would not have been overlooked. An experiment was performed in which tomato seeds were wet with a suspension of spores of the fungus and planted in sterile soil in a small flat in the laboratory. The plants were allowed to grow until about six inches in height but no sign of the disease was present although the plants were well watered each day. No attempt was made to recover the fungus from the soil.

**Dissemination by Rain and Wind.**—Once the disease appears in a field of tomatoes its spread is rapid. Since the spores are extruded from the pycnidium held together in a mucilaginous matrix, it is necessary to dissolve this substance

before any scattering of the spores takes place. Plates were exposed so that water falling upon diseased leaves during a gentle rain would drip into them. An examination of such plates showed the presence of only a small number of spores of the fungus. It might be mentioned that the plates overflowed with water and it is possible that some of the spores were washed away before they had settled upon the agar. From the diseased leaves, then, the spores are washed to the ground, and the soil about the diseased plants becomes a source of infection. Such infected soil splashed by falling rain upon the leaves of healthy plants will produce infection. This point has been tested in the greenhouse under controlled conditions. A water suspension of the fungous mycelium and spores was mixed into the upper three-fourths inch of soil in pots containing tomato plants about six inches in height. At intervals the plants were watered with a hose so that the infected soil particles were splashed upon the lower leaves. Infection of the lower leaves resulted with all the plants so treated while the plants in sterile soil similarly watered remained free from the disease.

While the spores are dissolved from the mucilaginous matrix and are lying in the water drops on the leaves the shaking of the leaves will serve to scatter the water suspensions of the spores from one plant part to another or from one plant to another. An examination of healthy and diseased tomato leaves just after an all night rain showed an abundance of spores of the fungus on the diseased leaves and also a relatively smaller number upon the healthy leaves. It seems evident that the spores upon the healthy leaves were splashed from the diseased leaves nearby, or the wind may have blown infected water drops from the diseased to the healthy leaves. The greatest abundance of spores was found in the water around the margin of the upper surface of the diseased leaves. As many as 189 spores were observed in a single field under the lower power of the microscope. The water which collects in the hollow along the midrib of the leaf was found to contain large numbers of spores. A very few spores were caught by means of funnels placed between diseased plants in such a way that spores splashed from diseased leaves might be blown into them and caught in very fine steel wool dipped in glycerine. It is possible that the force of the wind was not strong enough to cause the spores in any great numbers to enter the necks of the funnels, although Martin's (13) experiments along this line were more successful.

**Dissemination by Wind and Dust Particles.**—Plates of prune juice agar were exposed so that dust from the cultivation of a field in which the plants were infected, the previous year, would be blown upon them. When a light coating of dust had collected upon the plates they were examined for the presence of spores of *Septoria Lycopersici*. No spores were found at the time and the plates were set away and again examined after 24 hours. Spores of an *Alternaria* and a *Fusarium* were found in abundance but there was no evidence of the leaf-spot fungus. This experiment was repeated a number of times, but without positive results.

**Dissemination of Spores Upon the Hands of Pickers.**—In many instances it was found impracticable to wait until the plants were dry before picking. After picking in a field of wet infected plants the writer washed his hands and examined the water for spores of the leaf-spot fungus. In all cases they were found

in more or less abundance, depending upon the time elapsing between the picking and the washing of the hands. Spores in greater numbers per drop of water were found when the hands were washed immediately after picking from diseased plants. If a considerably longer time elapsed, fewer spores were found. The explanation for this would seem to lie in the fact that spores adhering to the hands were spread to the leaves of other plants which were also wet with rain or dew. The dissemination of spores on the hands of pickers is also reported by Martin (13) who made counts of the various examinations. There is little doubt that the picking of tomatoes when the plants are wet is a means of dissemination of this disease and the practice should be avoided whenever possible.

**Dissemination by Insects.**—In our field work the tomato crop was found to be attacked each year by the common tomato worm, *Phlegethontius quinquemaculata*. The worms usually appear earlier in the season than the more severe infection from the leaf-spot fungus. The plants during our three seasons' work were sprayed, at the time of the first appearance of the tomato worm, with a solution of lead arsenate, 2 pounds of powder to 50 gallons of water. One application was usually sufficient to control this insect. The Colorado potato beetle (*Leptinotarsa decemlineata* Say.) cannot be considered as a tomato pest in the locality where these experiments were conducted.

It is believed that insects as carriers of spores of the leaf-spot fungus in this locality can be eliminated to a large extent. Martin (13) found that the tomato worm and larvae and adults of the Colorado potato beetle and the lady bird beetle were rather important in the dissemination of the spores of *Septoria Lycopersici* both upon their bodies and within the feces. There is little doubt that where insects are present in large numbers in tomato fields at the time when the leaf-spot is severe they become important factors in the spread of the disease. The writer has frequently observed leaf-spot infection having its origin within or upon the edge of flea beetle injury to tomato leaves. Whether the insect carried the spores there or whether they merely lodged there was not determined, but Martin seems to think that infection may readily take place from spores carried directly by the flea beetle. It is obvious that insect control should be made a matter of common practice.

## CONTROL MEASURES

**Previous Work.**—The growing of varieties of tomatoes resistant or immune to the leaf-spot disease would be the ideal manner of controlling the disease. Such varieties have been sought over a period of years but so far without success. Protection of the plant from the attacks of the causal fungus has been tried widely. A review of the literature dealing with the control of the leaf-spot of tomato shows that the use of Bordeaux mixture is quite generally recommended both in the seed bed and in the fields.

Probably the earliest record of experimental work on the control of the disease by spraying is that of Halstead (9) in New Jersey. Several mixtures

were tried and it was found that Bordeaux mixture gave the greatest returns although the other mixtures, such as soap-Bordeaux, potash-Bordeaux and others, gave increased yields over the unsprayed plots. Other investigators have sprayed for the control of this disease with varying results. Norton (14) in experiments over a period of seven years states that an increase in yield can be expected, following five to seven applications of Bordeaux in the field. Martin (13) in field tests covering a period of three years found that spraying with Bordeaux mixture 4-4-50, Bordeaux soaps 4-2-3-50 and 4-4-3-50, copper soap 0.5-0-3-20 and Pickering's Bordeaux mixture 2-0.4-3-50, increased the yield of ripe fruit over that of the unsprayed plots. The percentage of leaves killed by the disease was also materially decreased by the application of any of the above materials. Reed (18) reports 4-4-50 Bordeaux mixture to be effective in the control of the disease, three applications being sufficient in an ordinary season and not more than five in an excessively wet season.



Fig. 2. A photograph, taken October 8th, showing how spraying has controlled the disease and kept the plants in a vigorous leafy condition. Spraying here has increased the total yield of fruit, but has prevented ripening, so that the yield of ripe fruit is less than on the unsprayed plots.

In Michigan in 1913, Eustace (4) was able to increase the yield of tomatoes from 5.2 tons per acre on the unsprayed plants to 12.5 tons per acre on those given four applications of Bordeaux mixture. The first application was made about one month after setting in the field and others followed at intervals of from ten days to two weeks.

Giddings (7) advised the use of Bordeaux mixture 5-5-50 if possible with the addition of 2 or 3 pounds of soap to each 50 gallons of fungicide. An appli-

cation should be made in the seed bed, when the plants have begun to grow well in the field, and every two weeks until at least four or five applications have been made in the field.

Fromme and Thomas (6) in Virginia found that three applications of Bordeaux mixture 4-5-50 and Pyrox increased the percentage of tomato leaves not infected with the leaf-spot fungus, 5.6 and 6.4 per cent respectively.

In spraying experiments carried on for three years at the Indiana Experiment Station, reported by Boyle (1) there was practically no difference in yield of ripe fruit from the plots sprayed with Bordeaux mixture and those unsprayed. During these trials the leaf-spot infection was not severe. However, in field experiments on a commercial scale in 1911, in which one acre plots were used, there was an increase of 558 pounds of ripe fruit on the unsprayed plot as compared to that of the plants sprayed with Bordeaux mixture. Boyle attributes this to the fact that weather conditions in August and September caused the plants to grow luxuriantly, and late in August the leaf-spot disease caused about one fourth of the leaves of the unsprayed plants to die. This killing of the foliage caused the plants to ripen their fruit before the first killing frost, while the plants protected from the disease by the spray coating continued to grow vegetatively rather than to mature their fruit.

In spraying for the control of the leaf-spot disease under the conditions of our experiments, two factors were taken into consideration: namely, the effect of spraying upon the disease, and its effect upon the proper ripening of the fruit within the limits of the time for delivery to the canning company. The usual contract from the canning company stipulates that they will receive the fruit until October 1, and after that date it is optional with the company whether the fruit is accepted or not. In one case, in 1920, the grower, with whom we cooperated in the spraying, was forced to lose from two to three tons of sound ripe sprayed fruit per acre because the company refused to take it after the prescribed date.

To be of commercial value, then, spraying must not only control the disease but through this control the yield of ripe fruit must be increased sufficiently to make the practice profitable.

As no previous work had been done in Pennsylvania upon the control of the leaf spot disease, the writer based his field experiments upon recommendations furnished by other investigators, using some of the spray mixtures which seemed to be most effective in other states.

Experiments in 1919.—During the season of 1919 the following spray mixtures were employed in the cold frame and in field spraying: Bordeaux mixture 4-4-50 and Bordeaux soap 4-4-3-50 in the field and Bordeaux soap 2-2-3-50 in the cold frame. While the results of this year's work were inconclusive they furnished data upon which further field trials were based during the two following seasons. Table 1 gives the data obtained from these experiments.

Table 1. Effect of Spraying upon the Yield of Ripe Fruit, 1919\*

| Plot No. | Cold Frame Treatment   | Field Spray            | Number of Applications | Yield of Ripe Fruit per Acre Pounds |
|----------|------------------------|------------------------|------------------------|-------------------------------------|
| 1        | None                   | Bordeaux 4-4-50        | 6                      | 31,822                              |
| 2        | "                      | Bordeaux 4-4-50        | 5                      | 33,341                              |
| 3        | Bordeaux soap 2-2-3-50 | " "                    | 6                      | 21,740                              |
| 4        | " "                    | " "                    | 5                      | 20,692                              |
| 5        | None                   | Bordeaux soap 4-4-3-50 | 6                      | 26,195                              |
| 6        | "                      | " "                    | 5                      | 22,979                              |
| 7        | "                      | No field spray         |                        | 34,586                              |
| 8        | Bordeaux soap 2-2-3-50 | Bordeaux soap 4-4-3-50 | 6                      | 22,783                              |
| 9        | " "                    | " "                    | 5                      | 16,932                              |
| 10       | " "                    | No field spray         |                        | 19,920                              |

Plots 1, 2, 5, 6 and 7 received acid phosphate at the rate of 450 pounds per acre, while plots 3, 4, 8, 9 and 10 received acid phosphate at the rate of 1,000 pounds per acre on one half and at the rate of 800 pounds per acre upon the other half. From the yields given it would seem that the optimum amount of this fertilizer for the tomato crop was about 450 pounds per acre. The interesting results from this year's work are the effect of five applications of Bordeaux mixture upon the yield, and the high yield of the check plot 7 which slightly outyielded the best of the sprayed plots. The results are also contradictory in that a higher yield of ripe fruit was obtained from the plots given five applications of Bordeaux mixture as compared to those receiving six applications, while with the Bordeaux soap, 4-4-3-50, the opposite was true.

For the following season the work was planned so that the factors of varieties, fertilization of the soil, manner of picking, and size and arrangements of the plots would be constant.

Although the results of spraying upon the yield of ripe fruit are inconclusive, the data show that of all the mixtures employed (namely, Bordeaux 4-4-50, Bordeaux soaps 4-4-3-50 and 2-2-3-50) were effective in reducing the amount of the disease. The field counts were made September 11. The data are presented in the following table:

\* The writer's absence at the close of the picking season made it impossible to obtain the yield of green fruit on the plots.

Table 2. Effect of Spraying upon Percentage of Infection, 1919

| Number of Plots<br>in Experiment | Field Spray               | Relative Percentage<br>of Infection |
|----------------------------------|---------------------------|-------------------------------------|
| 2                                | Bordeaux soap<br>4-2-3-50 | 34.5                                |
| 7                                | Bordeaux<br>4-4-50        | 27.4                                |
| 6                                | Bordeaux soap<br>4-4-3-50 | 33.5                                |
| 6                                | Unsprayed<br>check        | 66.9                                |

The relative percentage of infection was arrived at in the following manner: a number of infected plants were examined, and the number of infected green leaves and the number of dead laterals counted. Plants lightly and severely diseased were examined to get a working knowledge of the appearance of plants with various percentages of infection. Then each plant in the plots was examined and the relative percentage of infection estimated. The results presented in the table give the averages of the estimates of each plant in the plots. This method was followed throughout the entire period of the field work on the disease.

The best of commercial practices were followed in growing the seedlings and plants both in the cold frames and in the field. A well known make of traction sprayer was used in the field with which from 100 to 150 gallons of spray mixture could be applied per acre of plants at pressures varying from 75 to 100 pounds per square inch, when the plants were small, to 175 to 250 pounds per square inch during the latter part of the spraying season. The plots were sprayed from one direction only.

A special tomato boom used throughout these experiments made it possible to spray three rows at a time. Three nozzles to each row directed the spray from either side and from above the plants. The side nozzles were turned slightly upward so that the spray was applied to some extent directly and also in the form of a fine mist to the undersides of the leaves.

During the seasons of 1920 and 1921 only one variety of plants was grown. This was Chalk's Early Jewel which had been selected each year by Mr. Eagley so that it represented the best type of canning tomato in the community.

**Experiments in 1920.**—The experiments this year were run in duplicate. The plots consisted of three rows of 25 plants each and the two series were adjacent extending across almost the entire width of the field. Tomatoes were also set on three sides of the plots, of which three rows were given the same treatment in the field although these plants were not sprayed in the cold frame. There were no noticeable differences in the type of soil throughout the plots of both series. All plots received the same application of fertilizer. Spraying was continued until severe damage resulted to the crop from driving the sprayer through the field; the drop-nozzles caught upon the vines pulling off the fruit or in some cases taking out whole stems of the plants. Applications of the fungicides were made July 2, 13, 21, 29, August 5, 16, and 23. The spray mixtures used, the cold frame treatment of the plants, arrangement of plots, and yields of ripe and green fruit per acre are given in Tables 3, 4 and 5.

Table 3. Effect of Spraying on the Yield of Ripe and Green Fruit, Series I, 1920

| Plot | Cold Frame Treatment   | Field Spray 7 Applications | Lbs. of Ripe Fruit per Acre | Lbs. of Green Fruit per Acre | Total Yield |
|------|------------------------|----------------------------|-----------------------------|------------------------------|-------------|
| 1    | Bordeaux soap 2-2-3-50 | Bordeaux 4-4-50            | 15,139                      | 9,327                        | 24,466      |
| 2    | " "                    | Bordeaux soap 4-2-3-50     | 14,997                      | 8,331                        | 23,328      |
| 3    | Unsprayed check        | Unsprayed check            | 17,114                      | 996                          | 18,110      |
| 4    | Bordeaux soap 2-2-3-50 | Bordeaux soap 4-4-3-50     | 16,322                      | 8,160                        | 24,482      |
| 5    | " "                    | Copper soap 0.5-0-3-50     | 14,086                      | 4,298                        | 18,384      |
| 6    | " "                    | No field spray             | 13,314                      | 1,833                        | 15,147      |

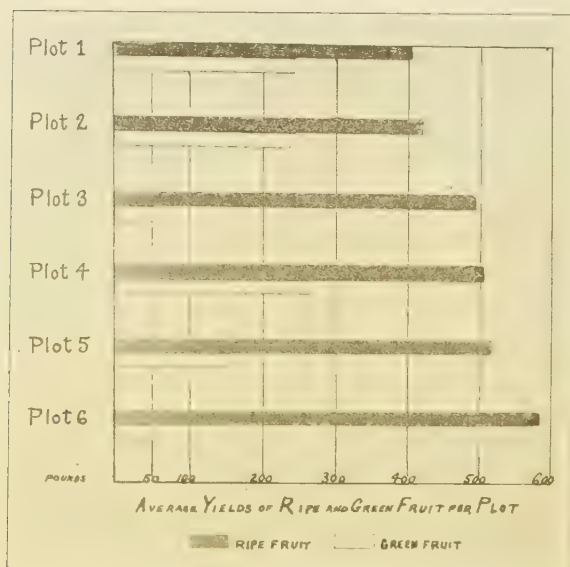


Fig. 3. Sprayed plots received five field applications and one cold frame application.

- Plot 1. Bordeaux 4-4-50.
- 2. Bordeaux soap 4-2-3-50.
- 3. Unsprayed both in cold frame and field.
- 4. Bordeaux soap 4-4-3-50.
- 5. Copper soap 0.5-0-3-50.
- 6. Bordeaux 2-2-50 in cold frame, nothing in field.

Table 4. Effect of Spraying on the Yield of Ripe and Green Fruit, Series II, 1920

| Plot | Cold Frame Treatment   | Field Spray 7 Applications | Lbs. of Ripe Fruit per Acre | Lbs. of Green Fruit per Acre | Total Yield |
|------|------------------------|----------------------------|-----------------------------|------------------------------|-------------|
| 1    | Bordeaux soap 2-2-3-50 | Bordeaux 4-4-50            | 11,621                      | 7,024                        | 18,645      |
| 2    | " "                    | Bordeaux soap 4-2-3-50     | 13,294                      | 7,741                        | 21,035      |
| 3    | Unsprayed check        | Unsprayed check            | 15,587                      | 2,490                        | 18,077      |
| 4    | Bordeaux soap 2-2-3-50 | Bordeaux soap 4-4-3-50     | 16,977                      | 10,336                       | 27,313      |
| 5    | " "                    | Copper soap 0.5-0-3-50     | 20,328                      | 6,257                        | 26,585      |
| 6    | " "                    | No field spray             | 25,488                      | 1,882                        | 27,370      |

Table 5. Average Yields of Ripe and Green Fruit on Plots, 1920

| Plot | Lbs. of Ripe Fruit per Acre | Lbs. of Green Fruit per Acre | Total  |
|------|-----------------------------|------------------------------|--------|
| 1    | 13,380                      | 8,175                        | 21,555 |
| 2    | 14,145                      | 8,035                        | 22,180 |
| 3    | 16,350                      | 1,743                        | 18,093 |
| 4    | 16,649                      | 9,158                        | 25,807 |
| 5    | 17,207                      | 5,276                        | 22,483 |
| 6    | 19,401                      | 1,857                        | 21,258 |

Table 6. Effect of Spraying upon the Percentage of Infection

| Plot | Cold Frame Treatment   | Field Spray            | Average Relative Percentage of Infection per Plot |
|------|------------------------|------------------------|---|
| 1    | Bordeaux soap 2-2-3-50 | Bordeaux 4-4-50        | 21.43   |
| 2    | " "                    | Bordeaux soap 4-2-3-50 | 18.01   |
| 3    | Unsprayed check        | Unsprayed check        | 65.76   |
| 4    | Bordeaux soap 2-2-3-50 | Bordeaux soap 4-4-3-50 | 16.79   |
| 5    | " "                    | Copper soap 0.5-0-3-50 | 45.92   |
| 6    | " "                    | No field spray         | 65.30   |

The interesting point in this connection is the fact that the plot receiving only the cold frame spray gave the greatest average yield of ripe fruit of all plots. The effect of spraying upon the development of the disease is expressed as relative percentage of infection per plot, the counts being made September 28. The results are given in Table 6.

From the results presented above, the presence of resin fish oil soap, 3 pounds to 50 gallons of spray material, increased the effectiveness of the mixture as a fungicide, when the same amount of copper sulphate was used as in the standard mixture. The smaller amount of copper sulphate used in copper soap mixture was not so effective as the Bordeaux mixture. There was little effect produced by the Bordeaux soap mixture, 2-2-3-50, employed only in the cold frame.

**Experiments in 1921.**—The same spray mixtures were tried out in 1921 as in the previous season. The only difference in the mixtures used was in the cold frame where the plants were sprayed with Bordeaux 2-2-50, no resin fish oil soap being available at the time of spraying. The plots were laid out in a single field comprising about one-half acre. Series II was located immediately in the rear of Series I. Potatoes were planted to the west and south of the plots while strawberries were grown to the north. This was the only field of tomatoes on the farm.

The sprayed plots of Series I were given five applications of the different mixtures on July 2, 14, 27, August 4 and 23. Those of Series II were sprayed at the same time with the exception of the first application, which was omitted. Spraying was started on Series I before the disease appeared in the field, and on Series II after the disease appeared. The spraying was conducted in the same manner as in 1920. The hot dry season of this year permitted fewer applications than during the previous season. The effect of spraying upon the yield of ripe and green fruit is seen in Tables 7 and 8.

Table 7. Effect of Spraying on Yield of Ripe and Green Fruit, Series I, 1921

| Plot | Cold Frame Treatment | Field Spray 5 Applications | Lbs. of Ripe Fruit per Acre | Lbs. of Green Fruit per Acre | Total Yield |
|------|----------------------|----------------------------|-----------------------------|------------------------------|-------------|
| 1    | Bordeaux 2-2-50      | Bordeaux 4-4-50            | 21,344                      | 2,548                        | 23,892      |
| 2    | " "                  | Bordeaux soap 4-2-3-50     | 24,698                      | 4,356                        | 29,054      |
| 3    | Unsprayed check      | Unsprayed check            | 31,363                      | 1,045                        | 32,408      |
| 4    | Bordeaux 2-2-50      | Bordeaux soap 4-4-3-50     | 25,962                      | 4,269                        | 30,231      |
| 5    | " "                  | Copper soap 0.5-0-3-50     | 26,354                      | 3,833                        | 30,187      |
| 6    | " "                  | No field spray             | 29,098                      | 2,962                        | 32,060      |

It will be seen from the above tables that in each series the unsprayed check plots gave higher yields of ripe fruit and lower yields of green fruit than the plots sprayed throughout the season.

Table 8. Effect of Spraying on Yield of Ripe and Green Fruit, Series II, 1921

| Plot | Cold Frame Treatment | Field Spray 4 Applications | Lbs. of Ripe Fruit per Acre | Lbs. of Green Fruit per Acre | Total Yield |
|------|----------------------|----------------------------|-----------------------------|------------------------------|-------------|
| 1    | Bordeaux 2-2-50      | Bordeaux 4-4-50            | 23,196                      | 4,966                        | 28,162      |
| 2    | " "                  | Bordeaux soap 4-2-3-50     | 26,158                      | 3,833                        | 29,991      |
| 3    | Unsprayed check      | Unsprayed check            | 29,468                      | 436                          | 29,904      |
| 4    | Bordeaux 2-2-50      | Bordeaux soap 4-4-3-50     | 25,742                      | 5,227                        | 30,969      |
| 5    | " "                  | Copper soap 0.5-0-3-50     | 24,045                      | 2,178                        | 26,223      |
| 6    | " "                  | No field spray             | 24,459                      | 2,701                        | 27,160      |

The effect of spraying upon the control of the disease is given in Tables 9 and 10. The counts were made September 27 in both series.

Table 9. Effect of Spraying upon the Percentage of Infection, Series I, 1921

| Plot | Cold Frame Treatment | Field Spray 5 Applications | Relative Percentage of Infection |
|------|----------------------|----------------------------|----------------------------------|
| 1    | Bordeaux 2-2-50      | Bordeaux 4-4-50            | 15.0                             |
| 2    | " "                  | Bordeaux 4-2-3-50          | 36.0                             |
| 3    | Unsprayed check      | Unsprayed check            | 86.4                             |
| 4    | Bordeaux 2-2-50      | Bordeaux soap 4-4-3-50     | 10.5                             |
| 5    | " "                  | Copper soap 0.5-0-3-50     | 31.2                             |
| 6    | " "                  | No field spray             | 79.0                             |

Table 10. Effect of Spraying upon the Percentage of Infection, Series II, 1921

| Plot | Cold Frame Treatment | Field Spray 4 Applications | Relative Percentage of Infection |
|------|----------------------|----------------------------|----------------------------------|
| 1    | Bordeaux 2-2-50      | Bordeaux 4-4-50            | 28.2                             |
| 2    | " "                  | Bordeaux soap 4-2-3-50     | 47.6                             |
| 3    | Unsprayed check      | Unsprayed check            | 80.6                             |
| 4    | Bordeaux 2-2-50      | Bordeaux soap 4-4-3-50     | 13.1                             |
| 5    | " "                  | Copper soap 0.5-0-3-50     | 62.0                             |
| 6    | " "                  | No field spray             | 82.6                             |

From the above tables it will be seen that in both series of plots those sprayed with the Bordeaux soap 4-4-3-50 gave the best control of the disease.

## DISCUSSION OF THE RESULTS OF SPRAYING IN 1920-1921

From the results obtained during the season of 1920, it will be seen that, for the plots receiving Bordeaux mixture 4-4-50 in the field, the average yield of ripe fruit was less than on any of the other sprayed plots or of the unsprayed checks. It is shown that, with the exception of the plots receiving Bordeaux soap 4-4-3-50, the average yield of green fruit was greater in the Bordeaux 4-4-50 than any of the other plots. There is little difference between the plots receiving Bordeaux mixture 4-4-50 and Bordeaux soap 4-2-3-50, either in average yield of ripe or green fruit. The greatest differences are observed between the average yields of ripe and green fruit on the plots sprayed with Bordeaux mixture 4-4-50, Bordeaux soap 4-2-3-50 and the plot receiving only the cold frame spray. It is especially to be noted that spraying throughout the season with any of the mixtures employed greatly increased the amount of green fruit at the close of the picking season. Since the green fruit was not utilized by the canning company contracting for the crop of ripe fruit, this represents a total loss to the grower. The greatest yield of ripe fruit from any of the plots was from that one sprayed in the cold frame alone.

It is also seen that any of the spray mixtures applied in the field gave a decided reduction of the disease as compared with the check plots. The application of Bordeaux soap 2-2-3-50 to the plants in the cold frame alone had no appreciable effect upon control of the disease nor upon the yield of ripe fruit, although there was less green fruit than from the plots given field applications of spray materials.

From the standpoint of total yield, however, the plot receiving field applications of Bordeaux soap 4-4-3-50 produced the greatest amount of fruit. Since picking for the cannery continued until October 13, this year, it is not likely that all the green fruit would have ripened in the locality before a killing frost.

\* The conclusion to be drawn from the experiments in 1921 is that spraying in the field, giving either four or five applications in addition to the cold frame spray, was not justified by the increased yields of fruit. In the case where five applications were given, the totally unsprayed plot outyielded in ripe fruit by at least 2,000 pounds per acre any of the plots sprayed in the field. The next highest yield of ripe fruit was from the plot given only the cold frame spray. In the case of the series of plots receiving only four applications of spray material in the field, the highest yield is again found from the totally unsprayed plot. In this case, however, the next highest yield was obtained from the plot receiving Bordeaux soap 4-2-3-50. There was little difference in yields from any of the sprayed plots or from the one receiving only the cold frame spray. The greatest difference was found between the yield of the sprayed plots and the check or totally unsprayed plot. It is again noted that the plot showing the greatest yield of green fruit at the close of the picking season also showed the

best control of the leaf-spot disease. The disease was controlled to some extent by all of the mixtures used in the field spraying, the best results being observed on the plot receiving Bordeaux soap 4-4-3-50.

The season of 1920 was regarded as unfavorable for tomato growing. There was an abundance of rainfall with cool days, and the fruit was slow in ripening. The following season, 1921, there was much hot weather, and there was very little precipitation in the locality where the experimental plots were located. The plants grew well both seasons, but during 1920 the fruit was later in setting and ripening than in 1921, which was considered one of the best seasons for the crop in this locality in recent years.

#### RELATIVE EFFICIENCY OF SPRAY MIXTURES USED

The efficiency of a spray mixture should be measured not only by its effect upon the disease, here expressed in terms of relative percentage of infection upon the plants, but also by its effect upon the yield of ripe and green fruit during the

Table 11. Relative Efficiency of Spray Mixtures Employed, 1920-1921

| Spray Mixture Employed                  | Average Yield Ripe Fruit in Lbs. per Acre | Average Yield Green Fruit in Lbs. per Acre | Total Yield | Average Relative Percentage of Infection per Plot |
|---|---|--|-------------|---|
| Bordeaux 4-4-50                         | 17,825                                    | 5,966                                      | 23,791      | 21.5  |
| Bordeaux soap 4-2-3-50                  | 19,787                                    | 6,065                                      | 25,852      | 33.8  |
| Bordeaux soap 4-4-3-50                  | 21,251                                    | 6,998                                      | 28,249      | 13.4  |
| Copper soap 0.5-0-3-50                  | 21,203                                    | 4,141                                      | 25,344      | 46.3  |
| Cold frame spray alone*                 | 23,000                                    | 2,345                                      | 25,345      | 75.6  |
| Check unsprayed in cold frame and field | 23,383                                    | 1,242                                      | 24,625      | 77.9  |

marketing season. In the table above the average efficiency of the various mixtures employed during the seasons of 1920 and 1921 is given. The results of the season of 1919 are omitted because of the different soil conditions due to a difference in the amounts of fertilizer added. No difference is made between the number of applications of the fungicides, since there was so little difference in

\* The cold frame spray in 1920 was Bordeaux soap 2-2-3-50, and in 1921 it was Bordeaux mixture 2-2-50.

the results obtained from spraying in the field before and after the disease had made its appearance.

It will be seen from the above table that for the two seasons, averaging the individual yields and percentages of infection for each plot, the Bordeaux soap 4-4-3-50 shows the highest average efficiency of any of the field sprays in controlling the disease. Of the field sprays employed, the Bordeaux soap 4-4-3-50 also gave slightly the greatest yield of ripe fruit and the highest yield of green fruit. The highest average yield of ripe fruit and the lowest yield of green fruit from any of the plots were obtained from the check plots receiving no spray whatever, followed closely by the plot sprayed in the cold frame. It is interesting to note that the high yield of ripe fruit and low yield of green fruit are associated with high relative percentage of infection upon the plants as seen in the unsprayed plots. It is a little surprising that this correlation is not followed out in the spray plots. For example, the plots showing the best control of the disease are those sprayed with Bordeaux soap 4-4-3-50. The yield of ripe fruit, following the indications given by the check, should be the lowest, and the yield of green should be the highest in this plot. For the green fruit this is true; but it is not the case for the ripe fruit, the yield of which is found to be greater than from any of the other sprayed plots, although the relative control of the disease on the other sprayed plots is much less than on the Bordeaux soap 4-4-3-50 plot.

It is also noted that the addition of resin fish oil soap to Bordeaux mixture greatly increases its effectiveness as a fungicide, probably because of its adhesive and spreading qualities. The lesser control of the disease by the use of Bordeaux soap 4-2-3-50 may be accounted for by the fact that the smaller amounts of lime in the mixture caused an incomplete reaction between the copper sulphate and the calcium oxide with the formation of a smaller amount of basic cupric sulphate, the active agent in copper-lime sprays.

The results upon the control of the leaf-spot disease in the field by the use of copper soap 0.5-0-3-50 and Bordeaux soap 4-2-3-50 are in striking contrast to those obtained by Pritchard and Clark (16) using the same mixtures in greenhouse tests. Their data give only the control of initial infection which they were able to reduce 98 per cent with both materials, while in our results on a commercial scale of spraying the total infection was reduced only 53.7 and 66.2 per cent, respectively, by the mixture on the average for the two years' spraying. In the case of Bordeaux soap 4-4-3-50 they were also able to reduce initial infection 98 per cent, while in our experiments in the field the total relative percentage of infection was reduced 86.6 per cent. The results obtained with the latter mixture are more nearly what one would expect from timely applications of this fungicide in the field. In the case of Bordeaux 4-4-3-50 our control was 78.5 per cent of the total infection, while they obtained only 62 per cent in the reduction of the initial infection. It is possible that our results would vary considerably if the total number of infections had been taken for each plant of the plots instead of estimating the relative percentage of infection as given on page 16. However, for the purposes of the experiment we feel that the method was sufficiently accurate.

## EFFECT OF SPRAYING UPON RIPENING

It has been stated by some investigators that spraying delays the ripening of the fruit, probably because of the fact that more leaves are retained by the sprayed plant through the protection against fungus and insect attacks. The greater amount of foliage permits less sunshine to fall upon the fruit which retards the ripening. Edgerton (3) found that there was a delay in ripening of early fruit on plants sprayed with Bordeaux 4-4-50, the unsprayed plants producing more ripe fruit at the earlier pickings. Pritchard and Clark (17) from results of three years' spraying in Indiana, Maryland, New Jersey, and Virginia, show an increase in yield of fruit from the sprayed plots, and state that if there was any delay in ripening it would be shown in the total yield for the season's picking.

Martin (13) states that there is a direct relation between the number of leaves retained upon the plant through spraying and the amount of green fruit at the end of the season. The results of Lloyd and Brooks (12) on the relative yield of early fruit from sprayed and unsprayed plants tends to bear out the above statement.

Boyle (1) concludes, from his observations in Indiana, that plants protected by a coating of Bordeaux mixture, when the disease appears late in the season, will continue to produce new foliage instead of maturing the fruit already set. Unsprayed plants in the same condition of growth when attacked will lose a considerable amount of foliage, causing them to ripen their set of fruit. He found, in a late attack of the fungus, that the unsprayed vines produced somewhat more ripe fruit per acre than the sprayed vines.

In our field work we found a definite correlation between the control of the tomato leaf-spot, measured by the relative percentage of infection, and the amount of green fruit on the plants at the close of the picking season.

The plots having the greatest yield of green fruit at the end of the picking season also showed the most effective control of the leaf-spot disease. The fact that the plots totally unsprayed gave higher yields of ripe fruit than the sprayed plots throughout the season would seem to show that there was a retarding effect brought about by the spraying, probably because of the shading of the fruit by the retention of leaves.

## SANITATION

While the results here reported show that spraying tomatoes for the control of leaf-spot is of questionable value, cases frequently occur where the disease is so severe that the plants yield few or no fruits. Such cases are usually the result of early infection, either in the seed bed or field, from the parasite which overwinters upon dead plants as has been shown by Levin and others. It is, therefore, of considerable importance to collect and burn the old vines after harvesting the fruit in order that they may not be a source of infection in the soil.

## SUMMARY

1. The leaf-spot disease of tomatoes, caused by *Septoria Lycopersici* Speg. causes severe defoliation of the plants.
2. Leaves, stems, and blossoms are attacked. Fruit from the most severely affected plants is small and of inferior quality and color.
3. The disease appears in the field about the first of July, usually upon a few scattered plants. From these as foci of infection it spreads throughout the field attacking by the middle of August practically every plant.
4. Insects as carriers of spores of the causal fungus are of no great importance in the locality where this work was done.
5. The disease is spread by the splashing of spores by rain, and by spores carried upon the pickers' hands.
6. The disease is greatly reduced by spraying with Bordeaux mixture 4-4-50, Bordeaux soaps 4-2-3-50 and 4-4-3-50, and copper soap 0.5-0-3-50. The best control of the disease resulted from spraying with Bordeaux soap 4-4-3-50.
7. The use of spray mixtures did not increase the yield of ripe fruit on sprayed plants over that from the unsprayed plants.
8. In the locality where this work was done the season is too short to allow all the fruit on sprayed plants to ripen.

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